Executive Summary

Big Roche a Cri Lake is a 205-acre impoundment (man-made lake) located in the Town of Preston, Adams County, in the Central Sand Plains Area of Wisconsin. Big Roche-a-Cri Lake has a maximum depth of 22 feet and an average depth of 9 feet. This is a mildly eutrophic lake with good water quality and fair-to poor water clarity. Both filamentous and planktonic algae are common in the lake, especially in the shallow areas of the lake.

Of the 23 aquatic macrophytes found in Big Roche a Cri Lake in 2008, 5 were emergent, 2 were floating-leaf rooted plants, 3 were free-floating plants and 13 were submerged plants. The latter included non-native invasives *Myriophyllum spicatum* (Eurasian Watermilfoil) and *Potamogeton crispus* (Curly-Leaf Pondweed). Aquatic plants occurred throughout Big Roche a Cri Lake, at 73.5% of all the sample sites to a maximum depth of 15 feet, where *Ceratophyllum demersum* was found. The deepest rooted aquatic plants—*Vallisneria americana* and *Myriophyllum spicatum*--were found at 13 feet in depth.

In 2008, the most frequently-occurring aquatic plant was *Vallisneria americana* (water celery), which was found at 51.34% of the sample sites. The only other two commonly-occurring aquatic plants in 2008 were *Ceratophyllum demersum* (Coontail), with 39.85% occurrence frequency, and *Myriophyllum spicatum* (Eurasian watermilfoil), with a 22% frequency of occurrence.

Vallisneria americana had the highest relative density of all the aquatic plants found in Big Roche a Cri Lake in 2008 (22% relative density). This was followed by *Ceratophyllum demersum* (20% relative density), *Myriophyllum spicatum* (10% relative density), and *Elodea canadensis* (9% relative density). All other aquatic plants had a less than 4% relative density.

Combining the relative frequency and relative density of a species into a Dominance Value illustrates how dominant that species is within the aquatic plant community. *Vallisneria americana* was the overall dominant plant in Big Roche a Cri Lake in 2008, with *Ceratophyllum demersum* sub-dominant overall.

The aquatic plant community of Big Roche a Cri Lake is characterized by average quality, good species diversity, and a significant tolerance to disturbance, the result of past disturbance. A healthy aquatic plant community is important because that plant community improves water quality, provides valuable habitat resources

for fish and wildlife, resists the spread of non-native species and check excessive growth of tolerant species that could crowd out the more sensitive species, thus reducing diversity.

MANAGEMENT RECOMMENDATIONS

1) Continue involvement of the Lake District in water quality monitoring through the Citizen Volunteer Lake Monitoring Program.

2) Continue involvement of the Lake District & volunteers in aquatic invasive species monitoring through the Citizen Lake Monitoring Program.

3) Chemical treatments for plant growth are still not recommended in Big Roche-a-Cri Lake due to the undesirable side effects of chemical treatments.

4) Continue with natural shoreland restoration. While the amount of restored shoreline has increased since 2004, there is still more to be done and there is still a fair amount of mowed lawn.

5) Continue to annually fine-tune the harvest plan and to engage in an integrated approach to the management of the aquatic plants and the aquatic invasives. The mechanical harvesting plan should be designed to remove nutrients, target Eurasian watermilfoil, provide navigation, and recreation where appropriate, prevent the spread of species that could become overabundant and improve habitat. It is important that evaluations be conducted on the lake to identify areas of Eurasian watermilfoil before spring harvesting starts. This will allow the fine-tuning of the harvesting map. A second evaluation should be done in the fall, after harvesting has ceased, in order to help identify areas that might need to be examined closely in the spring.

6) Continue to cooperate with programs in the watershed to reduce nutrient inputs to the lake. Currently nearly half of the relatively large watershed is in agriculture.

7) Eliminate the use of lawn fertilizers, both organic and inorganic, on properties around the lake.

The Aquatic Plant Community in Big Roche-a-Cri Lake, Adams County 2008

I. INTRODUCTION

An updated aquatic plant survey was conducted in summer 2008 by staff from the Wisconsin Department of Natural Resources and the Adams County Land & Water Conservation Department. A prior study of the aquatic macrophytes (plants) in Big Roche-a-Cri Lake was conducted during July 2004 by Water Resources staff of the West Central Region - Department of Natural Resources (DNR) and a member of the Big Roche-a-Cri Lake District. That was the first quantitative vegetation study of Big Roche-a-Cri Lake by the DNR. Qualitative assessments were conducted in May 1964 by WI Water Pollution Committee staff and in 1996 by North Central Region staff - DNR.

A study of the diversity, density, and distribution of aquatic plants is an essential component of understanding a lake ecosystem due to the important ecological role of aquatic vegetation in the lake and the ability of the vegetation to characterize the water quality (Dennison et al. 1993).

Ecological Role: All other life in the lake depends on the plant life - the beginning of the food chain. Aquatic plants and algae provide food and oxygen for fish, wildlife, and the invertebrates that in turn provide food for other organisms. Plants provide habitat, improve water quality, protect shorelines and lake bottoms, add to the aesthetic quality of the lake and impact recreation.

Characterize Water Quality: Aquatic plants serve as indicators of water quality because of their sensitivity to water quality parameters, such as water clarity and nutrient levels (Dennison et. al. 1993).

The updated study will provide information that is important for effective management of the lake, including fish habitat improvement, protection of sensitive wildlife areas, aquatic plant management and water resource regulations. The baseline data that it provides will be compared to past and future aquatic plant inventories and offer insight into any changes occurring in the lake.

Background and History: Big Roche a Cri Lake is a 205-acre impoundment (man-made lake) located in the Town of Preston, Adams County, in the Central

Sand Plains Area of Wisconsin. Big Roche-a-Cri Lake has a maximum depth of 22 feet and an average depth of 9 feet. The lake was formed in 1856 when a small dam was built on Big Roche-a-Cri River to form a mill pond of unknown size for operating a grist mill. Today's lake was formed when a new, larger dam was constructed on the same site in 1926 for power generation.

As an impoundment of Big Roche a Cri Creek, it has both an inlet and outlet. Through Big Roche a Cri Lake moves input from a very large watershed of 177 square miles that extends into the next county east. Downstream of Big Roche a Cri Lake is another impoundment, Arkdale Lake. Big Roche a Cri Creek ultimately empties into the Wisconsin River.

A lake association was formed sometime during the 1930's or 40's. Complaints from lake users to the WI-DNR concerning aquatic plant growth are recorded as early as 1954. Currently, the lake is managed by the Big Roche a Cri Lake District.

A 2000 watershed analysis of Big Roche-a-Cri Lake determined that phosphorus loading to the lake from the watershed was approximately 826 pounds per year (Foth and Van Dyke, 2000). The size of the watershed means that the lake to watershed ratio is 208:1. Lakes with a watershed to lake ratio greater than 10:1 tend to have water quality problems (Field 1994).

A study conducted from 2004-2006 showed that the summer average phosphorus concentration in Big Roche a Cri Lake placed Big Roche a Cri Lake in the "fair" water quality section for impoundments, and in the "mesotrophic" level for phosphorus. The total epilimnetic phosphorus levels has been creeping up in Big Roche a Cri Lake. In 1970, the earliest information available, eplimnetic total phosphorus was 2.65 micrograms/liter. By the summer of 1995, the eplimnetic total phosphorus averaged 18.46 micrograms/liter. It crept up to an average of 25.4 micrograms/liter by 1999. And in 2004-2006, it averaged 33.91 micrograms/liter. These levels suggest that nutrients are accumulating in the lake as time goes on.

The 2004-2006 study determination of various land uses in the Big Roche a Cri Lake watersheds (surface water and ground water). Figure 1 outlines the results of that study.

Figure 1: Land Use in the Big Roche a Cri Lake Watershed (2004-2006)

	Surface		Ground			Total
Big Roche a Cri						
Agriculture--Non Irrigated	4569.84	9.75%	1673.99	8.27%	6243.83	9.30%
Agriculture--Irrigated	18,088.50	38.59%	6729.19	33.26%	24817.69	36.98%
Government	285.43	0.61%	103.18	0.51%	388.61	0.58%
Grassland/Pasture	808.86	1.73%	505.77	2.50%	1314.63	1.96%
Residential	3113.97	6.64%	2495.54	12.34%	5609.51	8.36%
Water	1820.21	3.88%	821.37	4.06%	2641.58	3.94%
Woodland	18,185.17	38.80%	7901.84	39.06%	26087.01	38.88%
total	46,871.98	100.00%	20,230.88	100.00%	67102.86	100.00%

There is a long history of chemical control of aquatic plants and algae in Big Roche-a-Cri Lake (Figure 2). Multiple treatments were conducted in many years; in 1975 there were 10 treatments in one year. Up to one-fourth of the lake has been treated in any one year.

Some herbicides that are problematic were used.

1) Arsenic is highly toxic. Between 1959 and 1966, more than 10 tons of arsenic was applied to Big Roche-a-Cri Lake (Table 2). Arsenic is no longer allowed as an aquatic pesticide because it is highly toxic to all species. Since it does not break down, arsenic stays in the sediments, resulting in the necessity to treat lake sediments as hazardous waste.
2) Another toxic compound used in Big Roche-a-Cri was Silvex (2,2,4,5-TP). Silvex is now banned as a possible carcinogen (Table 2).
3) Broad-spectrum chemicals have been used, Diquat and Endothall compounds. These compounds kill all plant species and inadvertently open up areas for the introduction of exotic and invasive species. Almost 100 gal of Diquat compounds had been used between 1970 and 1978. Endothall products have been applied as 1) 77 gallons of Aquathol between 1967 and 1977 and 2) more than 5 tons of Hydrothol between 1965 and 1987 (Table 2).
4) The Hydrothol formulation of Endthall is more toxic to young fish.
5) Cutrine and CuSO4 are copper products that were used to kill algae and reduce swimmer's itch (Table 2). . Since copper is an element, it does not biodegrade further, building up the sediments. The drawbacks of copper treatments are:
    a) the very short effective time
    b) the toxicity of copper to aquatic insects, an important part of the food chain in a lake

c) the build up of copper in the sediments, resulting in sediments that are toxic to mollusks that are the natural consumers of algae in a lake.

Table 2. Herbicide Applied to Big Roche-a-Cri Lake

	Arsenic Trioxide (lbs.)	Silvex 2,4,5-TP	2,4-D (gal)	Cutrine (gal.)	Copper Sulfate (lbs.)	Diquat (gal.)	Endothall	Area Treated (acres)	# Treatments
1959	3720							33	2
1960	5220							47	
1962	4500							30	2
1963	1620							12	2
1964	2000							16	2
1965	1200						7.2g. 1200#	6	
1966	2700	35					25.4g.	23	1
1970			20	87	189	30		70	4
1972							25#	0.1	1
1975			14		975	36.4	23.6g. 150#	50	10
1976					450	9.5	12.5g. 550#	14	6
1977			10		550	6	9g. 500#	30	4
1978			10		350	17	1150#	23	3
1983							1200#	5.3	1
1984							1320 #	7	1
1985							1400#	8	1
1986							1400#	12	1
1987							2000#	8	1
Total	20,960	35	44	87	2514	98.9	77.7gal. 10,895#		

During the late 1970's or early 1980's a small cutter was used by groups of association members to cut 4-foot paths for lake access where needed.

In 1988, Big Roche-a-Cri Lake Association formed the Big Roche-a-Cri Lake District and purchased a mechanical harvester. Mechanical harvesting began in 1988. Records of harvesting were sent to the DNR from 1993-1995 and 1998-2004 (Figure 3). Records were not found for 1996-97. During those years for which there are records, over 5000 loads of aquatic plants, weighing more than 30 million pounds, have been removed from Big Roche-a-Cri Lake. The removal of vegetation from the lake helps counteract nutrient inputs; however, impoundments can be impacted by ongoing inputs of nutrients.

Figure 3. Removal of Aquatic Vegetation by Mechanical Harvesting in Big Roche-a-Cri Lake, 1988 - Present

	Loads removed	Approx. weight of a load (pounds)	Approx. Weight (tons)
1988	32	~6000	96
1989	250	7800	975
1990	216	6680	722
1991	287	6000	861
1992	210	6000	630
1993	260	6000	780
1994	193	6000	579
1995	125	6048	378
1996	208	6000	626
1997*	332	6000	996
1998	348	6000	1044
1999	358	6000	1074
2000	445	6000	1335
2001	325	6000	975
2002	509	6000	1527
2003	953	6000	2859
2004			963
Total	5051		16,420

* - A second harvester was purchased, so now two are operating.

Harvesting has generally started in Mid-May each year, sometimes as late as mid-June, and generally continues until late-September, sometimes as late as early October.

In 1996, the lake district produced a Lake Management Plan in order to purchase a second harvester. Recommendations were made to:

1) Protect the lake and watershed through town and county ordinances
2) Initiate a "Self-Help Monitoring Program" to obtain data annually on the lake

3) Reduce non-point source pollution through an education program and other measures
4) Protect water quality by developing an aquatic plant harvesting plan and purchasing a second harvester
5) The lake district also entered an agreement with native plant nurseries to remove wild celery tubers from the sediment to reduce the colonization of this species in the lake.

A survey of the residents during the planning process indicated that the most popular lake activity was fishing (88%); the largest perceived problem was aquatic plants (87%), requiring more aquatic plant removal (85%)

In 2001, the lake district contracted the University of Wisconsin – Eau Claire to produce an updated bathymetric map.

In 2003, Eurasian watermilfoil was found to have invaded Big Roche-a-Cri Lake. Like many exotic species, Eurasian watermilfoil is able to out-compete native species when introduced into a new area. Exotic species can dominate because the new environment does not usually support the diseases and herbivores that kept it in check in its native country. A 3-foot drawdown of the lake occurred during the winter of 2005-2006 to assist in Eurasian watermilfoil control.

Regular mechanical harvesting continues on Big Roche a Cri Lake. A grab sample review of harvested plants was conducted in September 2009 by taking several samples off of the two harvesters as they unloaded. In the samples from the east (shallower) end, the bulk of the plants harvested was *Vallisneria americana* (water celery), which has been abundant in BRC Lake for many years. Harvesting results may underestimate its presence, since its long strands sometimes lay over in the water and aren't reached by the harvesting blades. Other native aquatic plants found were *Elodea canadensis* (common waterweed), *Ceratophyllum demersum* (coontail) and *Potamogeton zosteriformis* (flat-stemmed pondweed).

Vallisneria americana also comprised the bulk of the plants harvested from the west end of the lake. Also found in the harvested aquatic plants from that load were *Elodea canadensis* (common waterweed), *Ceratophyllum demersum* (coontail) and *Potamogeton richardsonii* (clasping-leaf pondweed). Two invasive aquatic plants—*Myriophyllum spicatum* (Eurasian watermilfoil) and *Potamogeton* *crispus* (curly-leaf pondweed)—were present, but neither were found in large amounts.

These sample results were in keeping with the results of the updated aquatic plant survey done in 2008 on this lake, when *Vallisneria americana* was the most-frequently-occurring and dominant aquatic plant in the lake, with *Ceratophyllum demersum* occurring with the most density and second-most dominant aquatic plant in the lake.

II.METHODS

Field Methods

The 2004 aquatic plant survey was done using the rake-sampling method developed by Jessen and Lound (1962), with stratified random placement of transects. The shoreline was divided into 29 equal segments, with a transect perpendicular to the shoreline then randomly placed within each segment, using a random numbers table. One sampling site was randomly located in each depth zone (0-1.5ft, 1.5-5ft, 5-10ft and 10-20ft) along each transect. Using a steel thatching rake, four rake samples were taken at each sampling site, one rake sample from each quarter of a 6-foot diameter quadrat. The aquatic plant species that were present on each rake sample and their abundance were recorded.

However, the 2008 survey was done using the point-intercept method outlined by Madsen (1999) of the U.S. Army Corps of Engineers. The WDNR created a regular grid of sample points over the lake. These points were then downloaded onto a GPS unit. This allowed navigation to the points in the field. 455 points were located on Big Roche a Cri Lake, with 44 meters between sampling points. Due to low water levels, samples in 2008 were only taken at 412 points.

A depth for each sample point was recorded. Sampling was done with either a thatching rake on a rope for deeper areas or a pole-handled thatching rake for shallower areas. One sample was taken at each point. Plant taxa were noted and the abundance of each taxa were estimated, using a 3-point scale: 1 = 1/3 or less of the rake head covered; 2 = 1/3 to 2/3 of the rake head covered; 3 = over 2/3 of the rake head covered. Visual inspection was also made around each sample point and between sample points to record the presence of any species that did not occur at the sampling sites

Data Analysis

The percent frequency of each species was calculated (number of sampling sites at which it occurred/total number of sampling sites). Relative frequency was calculated (number of occurrences of a species/total occurrence of all species. The mean density was calculated for each species (sum of a species' density ratings/number of sampling sites). Relative density was calculated (sum of a species density/total plant density). The relative frequency and relative density was summed to obtain a dominance value.

Species diversity was calculated by Simpson's Diversity Index. The Aquatic Macrophyte Community Index (AMCI) developed by Nichols et. al. (2000) was applied to Big Roche-a-Cri Lake. Measures for each of seven categories that characterize a plant community are converted to values between 0 and 10 and summed.

The Average Coefficient of Conservatism and Floristic Quality Index were calculated, as outlined by Nichols (1998), to measure disturbance in the plant community. A coefficient of conservatism is an assigned value, 0-10, the probability that a species will occur in an undisturbed habitat. The Average Coefficient of Conservatism is the mean of the Coefficients for all species found in the lake. The Floristic Quality Index is calculated from the Coefficient of Conservatism (Nichols 1998) and is a measure of a plant community's closeness to an undisturbed condition.

III. RESULTS

PHYSICAL DATA

Many physical parameters impact the aquatic plant community. Water quality (nutrients, algae, clarity and alkalinity) influence the plant community as the plant community can in turn modify these parameters. Lake morphology, sediment composition and shoreline use also affect the macrophyte community.

WATER QUALITY

Trophic Status: Total Phosphorus, Chlorophyll-a and Water Clarity:

The trophic state of a lake is one measure of water quality, basically defining the lake's biological production status. **Eutrophic lakes** are very productive, with high nutrient levels, frequent algal blooms and/or abundant aquatic plant growth. **Oligotrophic lakes** are those low in nutrients with limited plant growth and small populations of fish. **Mesotrophic lakes** are those in between, i.e., those which have increased production over oligotrophic lakes, but less than eutrophic lakes; those with more biomass than oligotrophic lakes, but less than eutrophic lakes; often with a more varied fishery than either the eutrophic or oligotrophic lakes. The trophic state of a lake is a classification of its water quality. Phosphorus concentration, chlorophyll concentration and water clarity data are collected and combined to determine the trophic state.

Figure 4: Trophic Table

30-40	**Oligotrophic:** clear, deep water; possible oxygen depletion in lower depths; few aquatic plants or algal blooms; low in nutrients; large game fish usual fishery
40-50	**Mesotrophic:** moderately clear water; mixed fishery, esp. panfish; moderate aquatic plant growth and occasional algal blooms; may have low oxygen levels near bottom in summer
50-60	**Mildly Eutrophic:** decreased water clarity; anoxic near bottom; may have heavy algal bloom and plant growth; high in nutrients; shallow eutrophic lakes may have winterkill of fish; rough fish common
60-70	**Eutrophic:** dominated by blue-green algae; algae scums common; prolific aquatic plant growth; high nutrient levels; rough fish common; susceptible to oxygen depletion and winter fishkill
70-80	**Hypereutrophic:** heavy algal blooms through most of summer; dense aquatic plant growth; poor water clarity; high nutrient levels

Big Roche a Cri Lake = 55

Phosphorus is a limiting nutrient in many Wisconsin lakes and is measured as an indication of the amount of nutrient in a lake. Increases in phosphorus in a lake can feed algae blooms and, alternately, excess plant growth. Although there are several forms of phosphorus in water, the total phosphorus (TP) concentration is considered a good indicator of a lake's nutrient status, since the TP concentration tends to be more stable than other types of phosphorus concentration. For an impoundment lake like Big Roche a Cri Lake, a total phosphorus concentration below 30 micrograms/liter tends to prevent nuisance algal blooms. As noted earlier, Big Roche a Cri Lake's growing season (June-September) surface average total phosphorus level of 33.91 micrograms/liter is slightly over to the level at which nuisance algal blooms can be expected. The growing season phosphorus levels for 1995-2002 averaged 23 micrograms/liter for the same area of the lake (deep hole end). Growing season phosphorus levels have dramatically increased over the years. And areas of Big Roche a Cri Lake do have nuisance-level algal blooms, especially in the shallower east end.

Chlorophyll-a concentration provide a measurement of the amount of algae in a lake's water. Algae are natural and essential in lakes, but high algal populations can increase water turbidity and reduce light available for plant growth, as well as result in unpleasing odor and appearance. Studies have shown that the amount of chlorophyll a in lake water depends greatly on the amount of algae present; therefore, chlorophyll-a levels are commonly used as a water quality indicator. The 2004-2006 growing season (June-September) average chlorophyll concentration in Big Roche a Cri Lake was 14.15 micrograms/liter. Such an algae concentration places Big Roche a Cri Lake at the "fair" level for chlorophyll a results.

Water clarity is a critical factor for plants. If plants don't get more than 2% of the surface illumination, they won't survive. Water clarity can be reduced by turbidity (suspended materials such as algae and silt) and dissolved organic chemicals that color or cloud the water. Water clarity is measured with a Secchi disk. Average summer Secchi disk clarity in Big Roche a Cri Lake in 2004-2006 was 7.19 feet. This is good water clarity, putting Big Roche a Cri Lake into the "mesotrophic" category for water clarity.

Past results suggested that Big Roche a Cri was a mesotrophic lake. However, results from 2004 to 2006 suggest that Big Roche a Cri Lake is now in the "mildly eutrophic" trophic level. Such lakes have decreased water clarity, may be anoxic near the bottom and may have heavy algal and plant growth. These lakes are usually high in nutrients. Phosphorus testing from prior years (1995-2002) suggest that phosphorus in Big Roche-a-Cri Lake increases spatially as the lake is sampled going upstream, with higher nutrient concentrations in the east end.

In 2004, filamentous algae occurred at 18% of the sample sites overall. The highest occurrence was in the 0 to 1.5 foot depth zone (26%), although the 1.5 to 5 foot depth zone was close behind (21%). Thick films of planktonic algae were also common.

The 2008 survey found filamentous algae even more abundant, as it was present at 29.27% of the sample sites. This time, the highest level of filamentous algae was found in the 1.5-5 foot depth zone (68.06%), although the 0 to 1.5 foot depth zone also had a high occurrence of 53.57%. These increases are further indications that nutrient levels in Big Roche a Cri Lake are accumulating.

Hardness

The hardness or mineral content of lake water can also influence aquatic plant growth. The 1999-2002 hardness values in Big Roche-a-Cri Lake ranged from 108-113 mg/l $CaCO_3$ in the moderately hard water range. Testing results from 2004 to 2006 show Big Roche a Cri Lake surface water as "hard" water (average 145 milligrams/liter $CaCO_3$), less than the overall hardness average impoundments in Adams County of 166 milligrams/liter of Calcium Carbonate. Hard water lakes tend to support more aquatic plant growth than soft water lakes.

LAKE MORPHOMETRY

The morphometry of a lake is an important factor in determining the distribution of aquatic plants. Duarte and Kalff (1986) found that the slope of the littoral zone could explain 72% of the observed variability in the growth of submerged plants. Gentle slopes support more plant growth than steep slopes (Engel 1985).

Big Roche-a-Cri Lake has a narrow basin with a gradually sloped littoral zone and shallow depths over most of the lake. Shallow depths and gradual slopes favor plant growth.

SEDIMENT COMPOSITION

The 2004 aquatic plant survey evaluated the sediment of Big Roche a Cri Lake. The dominant sediment found in Big Roche-a-Cri Lake was sand, in all depth zones and throughout the lake. Although there were pockets of other sediment types found, none reached over 6% presence.

In some instances, aquatic plants may depend on the sediment in which they are rooted for their nutrients. Thus, the richness and texture of such sediments could determine the type and abundance of aquatic plants in a location. Sand has a large rough texture and generally contains fewer nutrients for growth than silt, clay or muck. However, since the 2005 survey found that 85% of the sites with sand sediment were vegetated, sand does not appear to be limiting aquatic plant growth in Big Roche a Cri Lake.

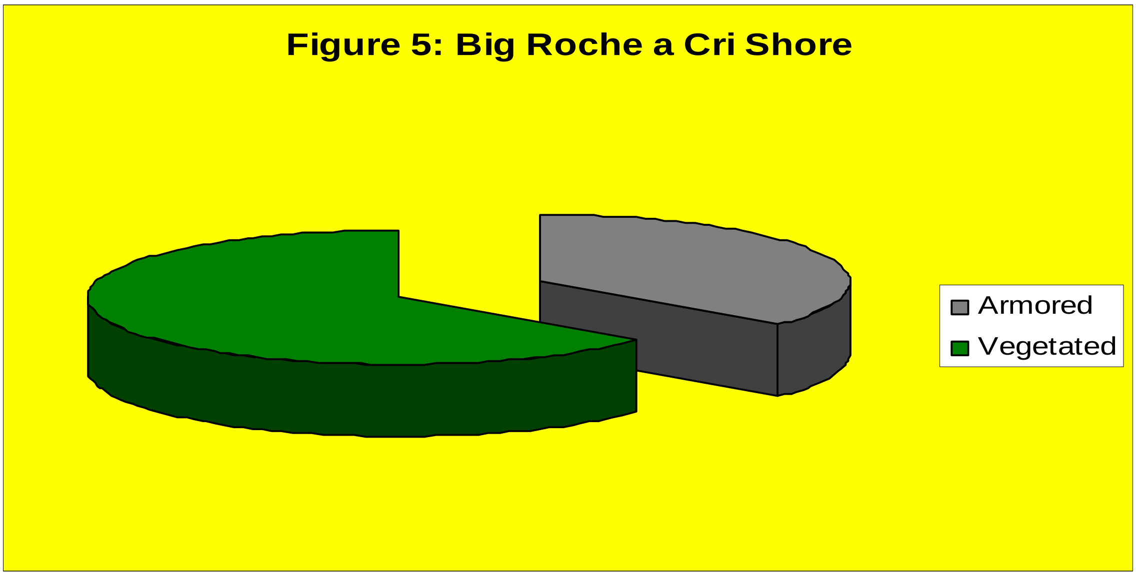
SHORELAND LAND USE

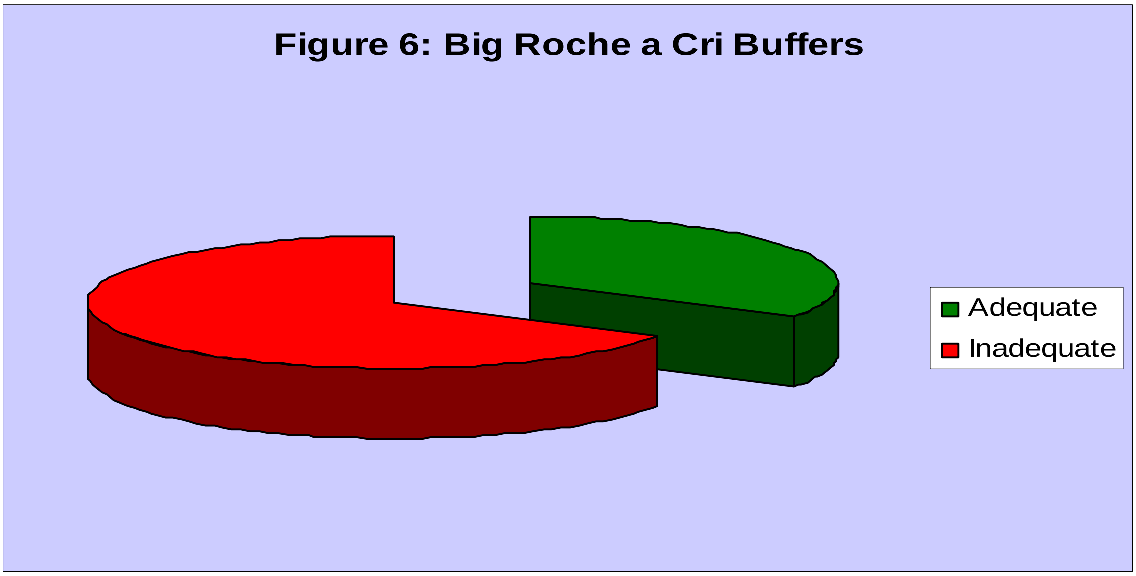
Land use can strongly impact the aquatic plant community, & therefore the entire aquatic community. Land use can directly impact the plant community through increased erosion & sedimentation and increased run-off of nutrients, fertilizers and toxics applied to the land. These impacts occur in both rural & residential settings.

Big Roche a Cri Lake has a total shoreline 6.1 miles (32,208 feet). Much of the lakeshore is in residential use. Many of the areas near the shore are very sandy and steeply sloped. A 2004 shore survey revealed that 64% of Big Roche a Cri Lake's shoreline was vegetated, with wooded vegetation being the most common native cover. Cultivated lawn was found at about 20% of the shore. The rest of the shore was a mix of active erosion, sand, rock and/or other hard structure. Disturbance of some kind was present at 72% of the sites, even those with some native vegetation. Since the survey was done, Big Roche a Cri Lake District was awarded a lake management plan implementation grant that allowed several property owners to install shore protection practices to reduce some of the erosion, which may have changed the distribution of shoreland types.

The Adams County Shoreline Ordinance defines 1000' landward from the ordinary high water mark as "shoreland". Under the ordinance, the first 35 feet landward from the water is a "buffer." Shoreland buffers are an important part of lake protection and restoration. These buffers are simply a wide border of native plants, grasses, shrubs and trees that filter and trap soil & similar sediments, fertilizer, grass clippings, stormwater runoff and other potential pollutants, keeping them out of the lake. A 1990 study of Wisconsin shorelines revealed that a buffer of native vegetation traps 5 to 18 times more volume of potential pollutants than does a developed, traditional lawn or hard-armored shore.

The 2004 inventory included classifying areas of the Big Roche a Cri Lake shorelines as having "adequate" or "inadequate" buffers. An "adequate" buffer was defined as one having the first 35 feet landward covered by native vegetation. An "inadequate" buffer was anything that didn't meet the definition of "adequate buffer", including native vegetation strips less than 35 feet landward. Using these definitions, only 33.6% (10821.89 feet) of Big Roche a Cri Lake's shoreline had an "adequate buffer" in 2004, leaving 66.4% (21386.11 feet) as "inadequate." Most of the "inadequate" buffer areas were found with mowed lawns and/or insufficient native vegetation at the shoreline to cover 35 feet landward from the water line.





AQUATIC MACROPHYTES PRESENT IN 2008

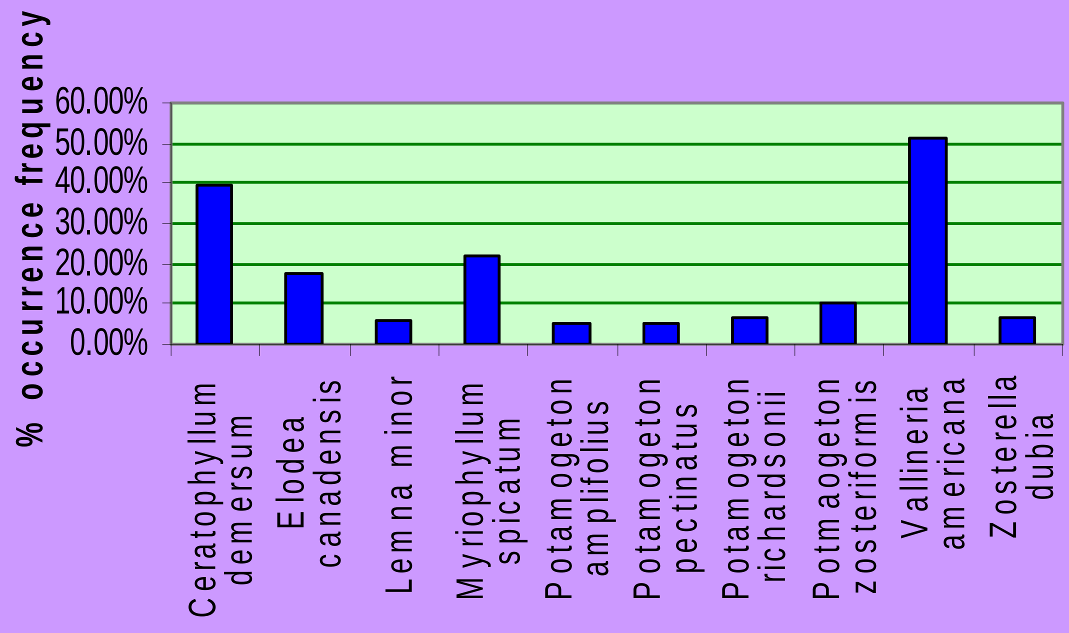
Of the 23 aquatic macrophytes found in Big Roche a Cri Lake in 2008, 5 were emergent, 2 were floating-leaf rooted plants, 3 were free-floating plants and 13 were submerged plants. The latter included exotic invasives *Myriophyllum spicatum* (Eurasian Watermilfoil) and *Potamogeton crispus* (Curly-Leaf Pondweed).

	Figure 7: Aquatic Plants Found in 2008	
Plant Type	**Scientific Name**	**Common Name**
Emergent	*Carex comosa*	Bristly Sedge
	Sagittaria cuneata	Arrow-Leaved Arum
	Scirpus americana	Hard-Stem Bulrush
	Scirpus validus	Softstem Bulrush
	Typha latifolia	Narrow-Leaved Cattail
Floating Leaf	*Brassenia schreberi*	Watershield
	Nuphar variegata	Yellow Pond Lily
Free-Floating	*Lemna minor*	Small Duckweed
	Spirodela polyrhiza	Large Duckweed
	Wolffia columbiana	Watermeal
Submergent	*Ceratophyllum demersum*	Coontail
	Chara	Muskgrass
	Elodea canadensis	Common Waterweed
	Myriophyllum spicatum	Eurasian Watermilfoil
	Potamogeton amplifolius	Large-Leaf Pondweed
	Potamogeton crispus	Curly-Leaf Pondweed
	Potamogeton epihydrus	Ribbon-Leaf Pondweed
	Potamogeton pectinatus	Sago Pondweed
	Potamogeton pusillus	Small Pondweed
	Potamogeton richardsonii	Clasping-Leaf Pondweed
	Potamogeton zosteriformis	Flat-Stem Pondweed
	Vallisneria americana	Water Celery
	Zosterella dubia	Water Stargrass

FREQUENCY OF OCCURRENCE

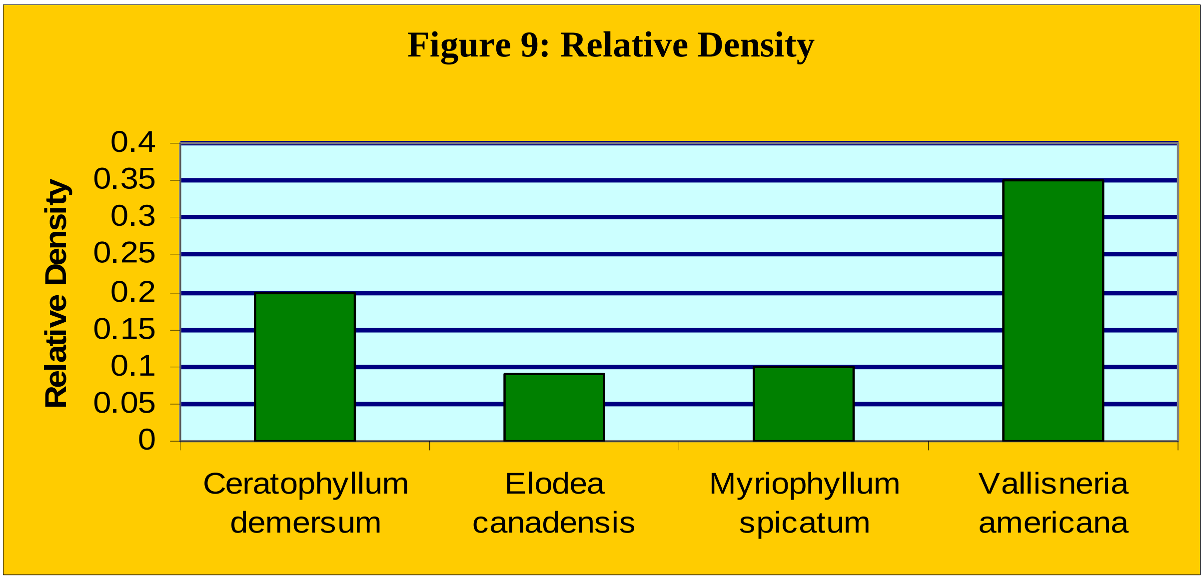
In 2008, the most frequently-occurring aquatic plant was *Vallisneria americana* (water celery), which was found at 51.34% of the sample sites. The only other two commonly-occurring aquatic plants in 2008 were *Ceratophyllum demersum* (Coontail), with 39.85% occurrence frequency) and *Myriophyllum spicatum* (Eurasian watermilfoil), with a 22% frequency of occurrence.

Figure 8: Most Frequently-Occurring Plants



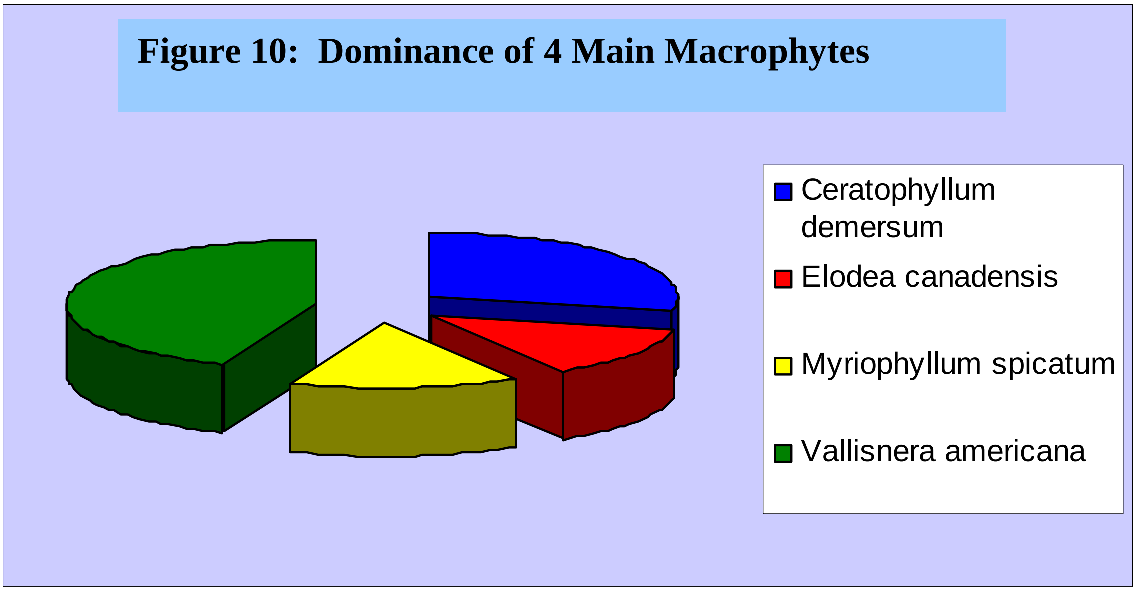
DENSITY OF OCCURRENCE

Vallisneria americana had the highest relative density of all the aquatic plants found in Big Roche a Cri Lake in 2008 (20% relative density). This was followed by *Ceratophyllum demersum* (20% relative density), *Myriophyllum spicatum* (10% relative density), and *Elodea canadensis* (9% relative density). All other aquatic plants had a less than 4% relative density.



DOMINANCE

Combining the relative frequency and relative density of a species into a Dominance Value illustrates how dominant that species is within the aquatic plant community. *Vallisneria americana* was the overall dominant plant in Big Roche a Cri Lake in 2008, with *Ceratophyllum demersum* sub-dominant overall.



DISTRIBUTION

Ceratophyllum demersum was the most frequently-occurring species in the 0 to 1.5 foot depth zone. *Myriophyllum spicatum*, *Potamogeton pectinatus* and *Potamogeton zosteriformis* were the second, third and fourth most frequently-occurring aquatic plants in this depth zone, in that order. 93.1% of the sample sites in this depth range contained aquatic vegetation. Filamentous algae occurred at 40.9% of the sites in this depth zone.

In the 1.5 to 5 foot depth zone, *Vallisneria americana* took hold, with a 71.7% occurrence frequency. *Ceratophyllum demersum* and *Elodea canadensis* were second and third most frequently occurring, with 44.2% and 42.5% respectively. The exotic invasive, *Myriophyllum spicatum*, was the fourth most-frequently-occurring aquatic plant in this depth zone. 94.7% of the sample sites contained aquatic vegetation in this depth range. Filamentous algae had an occurrence frequency of 40.8% here.

Vallisneria americana was also the most frequently-occurring aquatic plant in the 5 to 10 foot depth range, with an occurrence frequency of 76.5%. Next most frequently-occurring aquatic plant in this depth zone was *Ceratophyllum demersum*, with an occurrence frequency of 52.1%. *Myriophyllum spicatum* was the third most frequently-occurring plant here (26.9%). 92.2% of this depth zone contained aquatic vegetation, but filamentous algae were rare.

69.1% of the sample sites in the 10 to 20 foot depth zone had no aquatic vegetation. In the sites that did have aquatic vegetation in this depth zone, *Vallisneria americana* and *Ceratophyllum demersum* tied for the most frequently-occurring plant, with both having a 68.58% occurrence frequency. *Myriophyllum spicatum*, although the third most frequently-occurring aquatic plant in this depth zone, had an occurrence frequency of only 10.5%. No filamentous algae were found in this depth zone.

Aquatic plants occurred throughout Big Roche a Cri Lake, at 73.5% of all the sample sites to a maximum depth of 15 feet, where *Ceratophyllum demersum* was found. The deepest rooted aquatic plants—*Vallisneria americana* and *Myriophyllum spicatum*--were found at 13 feet in depth.

60.9% of the sites in the western third of the lake were vegetated. This area of the lake included many sample points over 10 feet deep. In the middle third of the lake, 87% of the sites were vegetated. Most of this water was less than 10 feet deep. In the eastern end of the lake, 96.8% of the lakebed was vegetated. The east end contains no depths over 5 feet.

Based on the Secchi disc clarity from 2004-2008, the predicted maximum rooting depth would be 12.8 feet. Considering the maximum depth at which rooted aquatic plants were found in 2008 was 13 feet, the predicted maximum rooting depth is similar to the actual rooting depth.

Lakewide species richness was 2.55 per sample site. The west end of the lake, which contains the deepest water, had a species richness of only 1.23 per site. Species richness increased the further east in the lake the sample point occurred. Species richness for the middle third of the lake was 2.34 per site. The far east end had a species richness of 3.62 per site.

THE AQUATIC PLANT COMMUNITY

The Simpson's Diversity Index was 0.87, indicating good species diversity. This was down slightly from the 2004 ranking of .886. A rating of 1.0 would mean that each plant in the lake was a different species (the most diversity achievable).

The Aquatic Macrophyte Community Index (AMCI) for Big Roche-a-Cri Lake in 2004 was 49. This value was below average quality for lakes in Wisconsin and in the lowest quartile of lakes in the North Central Region. The highest value for this index is 70. The 2008 AMCI was substantially higher at 54.

A Coefficient of Conservatism and a Floristic Index calculation were performed on the field results. Technically, the average Coefficient of Conservatism measures the community's sensitivity to disturbance, while the Floristic Index measures the community's closeness to an undisturbed condition. Indirectly, they measure past and/or current disturbance to the particular community.

Figure 11: AMCI for Big Roche a Cri Lake

Category	Parameter	2004	Parameter	2008
Maximum Rooting Depth	13 feet	7	15 feet	9
% Littoral Zone Vegetated	87%	10	73.50%	10
Simpson's Diversity Index	0.886	8	0.87	7
# of Species	25	9	23	9
Rel Freq of Exotic Species	13%	4	10.10%	4
Rel Freq of Submergent Species	61%	6	81.20%	10
Rel Freq of Sensitive Species	8%	5	7.60%	5
Total AMCI		49		54

Previously, a value was assigned to all plants known in Wisconsin to categorize their probability of occurring in an undisturbed habitat. This value is called the plant's Coefficient of Conservatism. A score of 0 indicates a native or alien opportunistic invasive plant. Plants with a value of 1 to 3 are widespread native plants. Values of 4 to 6 describe native plants found most commonly in early successional ecosystem. Plants scoring 6 to 8 are native plants found in stable climax conditions. Finally, plants with a value of 9 or 10 are native plants found in areas of high quality and are often endangered or threatened. In other words, the lower the numerical value a plant has, the more likely it is to be found in disturbed areas.

The 2008 Average Coefficient of Conservatism was 5.03, up slightly from the 2004 average of 4.42. Both these numbers are in the lowest quartile for all Wisconsin lakes and lakes in the North Central Hardwood Region. This suggests the Big Roche a Cri Lake aquatic plant community is among the group of lakes in Wisconsin and in the region that are the most tolerant of disturbance.

The Floristic Quality Index for 2008 was 24.19. This is an increase over the 2004 ranking of 21.064. While the 2004 reading was below average for the lakes in Wisconsin, but above average for the North Central Hardwoods Region, the 2008 level is slightly above average for both scales. This suggests that the aquatic plant community in Big Roche a Cri Lake has been impacted by near average amount of disturbance.

Figure 12: Floristic Quality and Coefficient of Conservatism of Big Roche-a-Cri Lake, Compared to Wisconsin Lakes and North Central Wisconsin Lakes.

	Average Coefficient of Conservatism*	Floristic Quality**
Wisconsin Lakes	5.5, 6.0, 6.9	16.9, 22.2, 27.5
NCHR	5.2, 5.6, 5.8	17.0, 20.9, 24.4
Big Roche a Cri Lake	5.03	24.19

* Values indicate the highest value of the lowest quartile, the mean and the lowest value of the upper quartile--Average Coefficient of Conservatism for all Wisconsin lakes ranged from a low of 2.0 (the most disturbance tolerant) to a high of 9.5 (least disturbance tolerant).
** Lowest Floristic Quality was 3.0 (farthest from an undisturbed condition) and the high was 44.6 (closest to an undisturbed condition).

Disturbances can be of many types:

1) Physical disturbances to the plant beds result from activities such as boat traffic, plant harvesting, chemical treatments, the placement of docks and other structures and fluctuating water levels.
2) Indirect disturbances are the result of factors that impact water clarity and thus stress sensitive species by resuspension of sediments, sedimentation from erosion and increased algae growth due to nutrient inputs.
3) Biological disturbances include competition from non-native/invasive plant species, grazing from an increased population of aquatic herbivores and destruction of plant beds by a fish or wildlife population.

Major disturbances in Big Roche-a-Cri Lake include shoreline development, past herbicide treatments, invasion of exotic species and mechanical plant harvesting.

Comparison of 1964, 1996, 2004 and 2008 Aquatic Plant Assessments

The 1964 and 1996 plant surveys were not quantitative surveys using the same methods as the 2004 plant study. The earlier surveys were qualitative, not designed to record all species, but possibly just to characterize the common species. And since the 2004 aquatic plant survey was done using the transect method, while the 2008 survey was done using the point intercept method, none of these results can be compared very specifically. However, it is possible to look at species present and relative frequencies as some indication as to changes in the aquatic plant community of Big Roche a Cri Lake.

In 1964, a simple species list was made and the dominant species was identified. The 1964 assessment found that curly-leaf pondweed was the dominant species, with sago pondweed, flat-stem pondweed and wild celery also present.

In 1996, Big Roche-a-Cri Lake was divided into 3 areas and qualitative assessments of the plant communities were made within each area. The species in each area were characterized as scattered, common, abundant or thick. Because of the different methods, direct comparisons can not be made, but some observations can be compared.

The total number of species and number of species recorded in each area increased between 1964 and 1996 and again between 1996 and 2004 (see Figure 11). This is likely due to increasingly more rigorous studies.

The dominant aquatic plant species changed from *Potamogeton crispus* (an invasive) in 1964 to *Vallisneria americana* in 1996, then to *Ceratophyllum demersum* in 2004, and back to *Vallisneria americana* in 2008.

Since a quantitative survey was not conducted in 1996, the only comparison that can be made is in the qualitative assessments of each species in each of the areas delineated in 1979.

In area 1, upstream and east of Highway 13, 8 species were recorded in 1996, 21 species were recorded in 2004, and 22 species were found in 2008. Other changes included:

1) In 1996, *Zosterella dubia* was characterized as thick, but by 2004 and 2008, it was present in only a few spots at this end.
2) *Elodea canadensis* has been common-to-abundant over the years and was the most frequently-occurred plant in the east end in 2008.
3) *Potamogeton zosteriformis* remained abundant in this area in 2008.
4) *Myriophyllum sibiricum* and *Potamogeton nodusus* were not found in the east end in 2008.
5) *Potamogeton crispus* was found at only five sample points at the east end in 2008 and was not dense.
6) *Nuphar variegata* was sparsely present in 2008.

7) In 2008, all three species of duckweed (*Lemna minor, Spirodela polyrhiza* and *Wolffia columbiana*.) were abundant in the east end.
8) In 2008, a new species, *Potamogeton epihydrus*, was found here.

Figure 13. Big Roche-a-Cri Lake Aquatic Plant Species, 1964-2008

1964	1996	2004	2008
<u>EMERGENTS</u>			
		Carex comosa	*Carex comosa*
		Cicuta bulbifera	
		Impatiens capensis	
		Rumex	*Sagittaria cuneata*
		Salix exigua	*Scirpus americana*
		Scirpus validus	*Scirpus validus*
		Typha latifolia	*Typha latifolia*
<u>FLOATING-LEAF</u>			*Brassenia schreberi*
	Nuphar variegata	*Nuphar variegata*	*Nuphar variegata*
<u>FREE-FLOATING</u>			
		Lemna minor	*Lemna minor*
		Spirodela polyrhiza	*Spirodela polyrhiza*
			Wolffia columbiana
<u>SUBMERGENTS</u>			
	Ceratophyllum demersum	*Ceratophyllum demersum**	*Ceratophyllum demersum*
			Chara spp
	Elodea canadensis	*Elodea canadensis*	*Elodea canadensis*
	Myriophyllum sibiricum		
		Myriophyllum spicatum	*Myriophyllum spicatum*
		Najas guadelupensis	
		Potamogeton amplifolius	*Potamogeton amplifolius*
*Potamogeton crispus**	*Potamogeton crispus*	*Potamogeton crispus*	*Potamogeton crispus*
			Potamogeton epihydrus
		Potamogeton illinoiensis	
		Potamogeton natans	
	Potamogeton nodosus		
Potamogeton pectinatus	*Potamogeton pectinatus*	*Potamogeton pectinatus*	*Potamogeton pectinatus*
		Potamogeton pusillus	*Potamogeton pusillus*
	Potamogeton richardsonii	*Potamogeton richardsonii*	*Potamogeton richardsonii*
Potamogeton zosteriformis	*Potamogeton zosteriformis*	*Potamogeton zosteriformis*	*Potamogeton zosteriformis*
Vallisneria americana	*Vallisneria americana**	*Vallisneria americana*	*Vallisneria americana**
	Zosterella dubia	*Zosterella dubia*	*Zosterella dubia*

*** -** Dominant species

In the mid-area of the lake, just west of Highway 13, 17 species of aquatic plants were found in 2008, up from 15 in 2004 and substantially increased from the 4 recorded in 1996. Other changes included:

1) By 2008, *Vallisneria americana* was re-established as the dominant, most abundant aquatic plant in this area, a change from 2004, when *Ceratophyllum demersum* held this spot.
2) Although *Ceratophyllum demersum* was no longer the dominant aquatic plant in this area, it remained abundant.
3) This area of the lake had the most occurrences of the exotic *Myriophyllum spicatum.* However, it was not as abundant and dense at it was found in the 2004 survey.
4) Although all three duckweeds present in the east end were also present in the mid-lake area, they occurred less frequently in 2008 than they had in 2004.
5) A new species, *Potamogeton epihydrus*, was found in the mid-lake area in 2008.

The dam for Big Roche a Cri Lake is located at the west end of the lake. This is the deepest area of the lake. In 1996, 4 species were recorded in this area of the lake. In 2004, there were 11 species found. 10 species were found in the west end of the lake in 2008. Changes in 2008 included:

1) *Potamogeton zosteriformis* was sparse in this area, rather than common.
2) *Ceratophyllum demersum* was abundant in 2008, rather than scattered as it was in earlier surveys.
3) Although the exotic *Myriophyllum spicatum* was still present in this area of the lake, it was not as common or as dense as it was in 2004.
4) No floating-leaf, free-floating or emergent aquatic plants were found in this section of the lake (this could be a function of the collection method).
5) *Potamogeton crispus*, an exotic invasive, was found at only one site in this section of the lake.

The primary invasive aquatic plant continues to be *Myriophyllum spicatum.* Although *Potamogeton crispus* is present in all three sections of the lake, it is not frequently-occurring and is not found in high densities.

Figure 14: Comparison of Plants Found in Various Surveys

Plant Type	Scientific Name	1964	1996	2004	2008
Emergent	*Carex comosa*			x	x
	Cicuta bulbiferea			x	
	Impatiens capensis			x	
	Rumex spp			x	
	Sagittaria cuneata				x
	Salix exigua			x	
	Scirpus americana				x
	Scirpus validus			x	x
	Typha latifolia			x	x
Floating Leaf	*Brasenia schreberi*				x
	Nuphar variegata		x	x	x
Free-Floating	*Lemna minor*			x	x
	Spirodela polyrhiza			x	x
	Wolffia columbiana				x
Submergent	*Ceratophyllum demersum*		x	x	x
	Chara				x
	Elodea canadensis		x	x	x
	Myriophyllum sibiricum		x		
	Myriophyllum spicatum			x	x
	Najas guadelupensis			x	
	Potamogeton amplifolius			x	x
	Potamogeton crispus	x	x	x	x
	Potamogeton epihydrus				x
	Potamogeton illinoiensis			x	
	Potamogeton natans			x	
	Potamogeton nodosus		x		
	Potamogeton pectinatus	x		x	x
	Potamogeton pusillus			x	x
	Potamogeton richardsonii		x	x	x
	Potamogeton zosteriformis	x	x	x	x
	Vallisneria americana	x	x	x	x
	Zosterella dubia		x	x	x

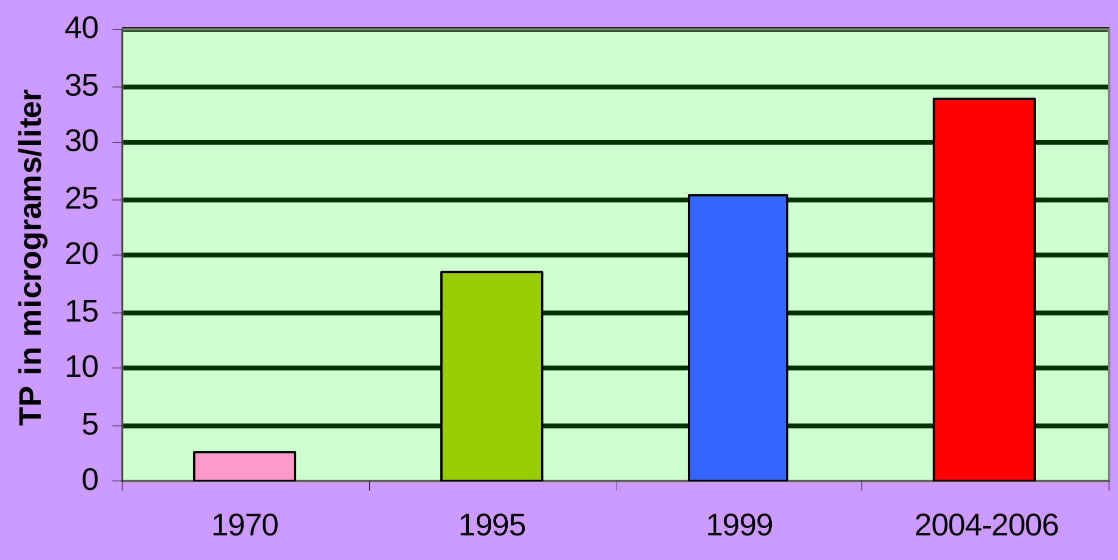
DISCUSSION

Based on water clarity, chlorophyll and phosphorus data, Big Roche-a-Cri Lake is a mildly eutrophic lake with good water quality and fair-to-poor water clarity. This trophic state should support significant plant growth and occasional algae blooms.

Overall, filamentous algae occurred at 30.7% of the sites, an increase from the overall occurrence in 2004 of 18%. Only 13.1% of the sites were in the west end of the lake had filamentous algae, but in the middle of the lake, 51.7% of the sites had filamentous algae and 60.3% of the east end sites had filamentous algae. Filamentous algae declined with increasing depth. Thick films of planktonic algae were also common, especially at the shallower end.

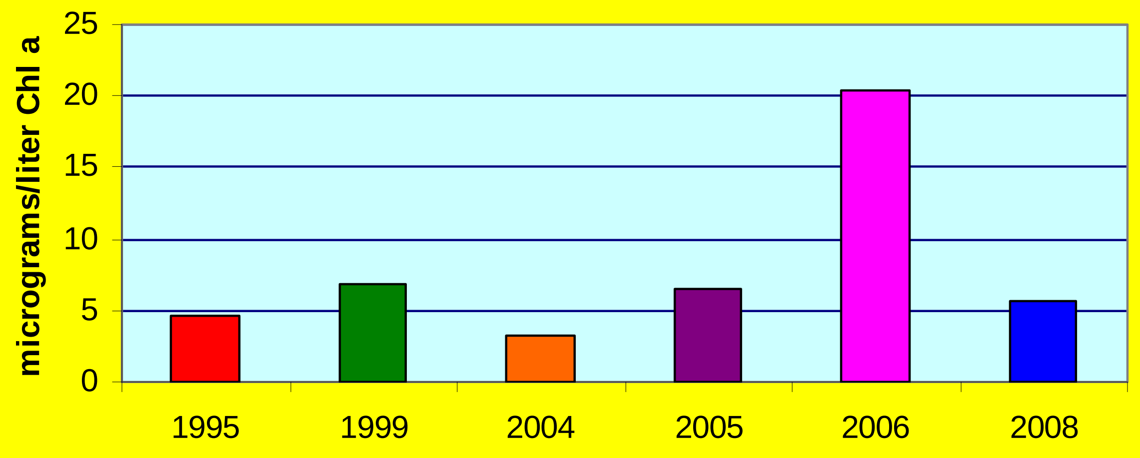
Phosphorus (nutrients) increased substantially from 1995 to 2006, as shown in Figure 13, verifying the increasing accumulations of nutrients in Big Roche a Cri Lake as time passes. Increased nutrients usually result in increased algae (chlorophyll), but the nutrients could also be used to feed increased plant growth or increased filamentous algae (which are not measured in the chlorophyll sampling techniques).

Figure 15: Phosphorus Level Increases



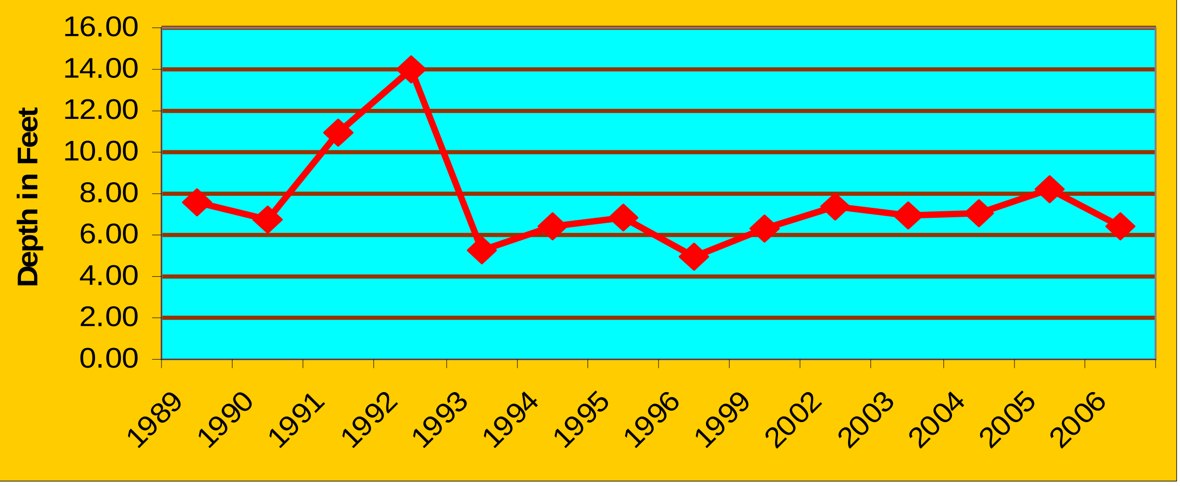
Except for a spike in the very hot dry year of 2006, Chlorophyll-a levels in Big Roche a Cri Lake have remained fairly low, especially for an impoundment.

Figure 16: Chlorophyll-a Levels 1995-2008



Growing season water clarity averages generally were in the 6 to 8 foot depth range from the late 1980s through 2008 (1991 & 1992 were two exceptions).

Figure 17: Growing Season Water Clarity Averages



The large ratio of watershed size to lake size tends to result in a concentrating of the nutrients into the lake. This is common with impoundments. Agricultural use, especially irrigated agriculture, is found in nearly one-half of the watershed, contributing significantly to the nutrient phosphorus load.

Adequate nutrients (mesotrophic status), the hard water, the shallow depth in most of the lake and the gradually sloped littoral zone favor plant growth in Big Roche-a-Cri Lake. The dominance of high-density sand sediments in Big Roche-a-Cri Lake do not appear to limit the density of plant growth. Favorable silt and muck sediments occur mainly in the east end of the lake.

There is a long history of chemical use for treating aquatic plant growth and algae in Big Roche-a-Cri Lake, 1959-1987. In some years, up to 10 treatments a year were conducted and up to one-quarter of the lake was treated at a time. Specifically,

1) Two products that are now banned because of their toxicity had been used for 7 years.
2) Broad-spectrum chemicals have been used for 13 years.
3) Two chemicals that do not biodegrade, but build up in the sediment, resulting in toxic sediment have been used
4) Chemicals that are toxic to young fish had been used for 11 years.

Since 1988, mechanical harvesting has been conducted in Big Roche-a-Cri Lake and has removed more than 30 million pounds of plant material. This removal of vegetation could help with nutrient reduction, but impoundments have continuous nutrient input from the river and watershed, which may counteract some of the nutrient removal. In order to counter the estimated yearly 826-pound phosphorus load to Big Roche-a-Cri, harvesting would have to remove 115-257 tons of plant material a year (based on tissue phosphorus concentrations of aquatic plants in area lakes). Since, Big Roche-a-Cri Lake District has been removing an average of 694 tons per year (1260 tons per year since the purchase of a second harvester), some progress is being made at removing some of the phosphorus load.

Big Roche-a-Cri Lake has some protection by natural shoreline cover (wooded, shrub, native herbaceous growth). Wooded cover was encountered frequently and had a high coverage level. However, disturbed shoreline was also frequently encountered. In particular, cultivated lawn, one type of disturbed shore, covered 20% of the shoreline. Areas with cultivated lawn impact the lake through increased run-off of lawn fertilizers, pesticides and pet wastes into the lake. The short blades and root systems of mowed lawn does not effectively slow run-off to the lake or absorb water, nutrients and toxics as well. Expanding the buffer of natural vegetation along the shore will help prevent shoreline erosion and help reduce additional nutrient/chemical run-off that can add to algae growth and sedimentation of the lake bottom.

Changes 1964-2008

Qualitative comparisons of the 1964, 1996, 2004 and 2008 aquatic plant communities were used to determine changes in the plant community. Of the 3 areas the lake had been divided into:

1) Species that are tolerant of lower water clarity have increased: *Certophyllum demersum, Elodea canadensis, Lemna minor, Wolffia columbiana* and *Spriodela polyrhiza.*
2) The non-native watermilfoil (*Myriophyllum spicatum)* has been introduced and has remained a management issue.
3) The introduced milfoil may be out-competing native species: two native species, *Potamogeton nodosus* and *Myriophyllum sibiricum,* appear to have disappeared from the lake entirely.
4) The dominant species have changed from *Potamogeton crispus* (curly-leaf pondweed) in 1964 to *Vallisneria americana* in 2008. Harvesting early in the season may have controlled the exotic curly-leaf pondweed. This allowed *Vallisneria americana* to become dominant as the water clarity increased due to nutrient removal.
5) Dominance of species changed again. From the 1996 dominant *Vallisneria americana,* there was a shift to *Ceratophyllum demersum* in 2004, then a shift back to *Vallisneria americana* in 2008. However, since *Ceratophyllum demersum* remains abundant, this could switch again. Since it is not a rooted plant, it floats in the water column just under the surface and is therefore not dependent on light availability to the bottom of the lake or being subjected to competition for rooting space.
6) The increase in other species may indicate declining water clarity: *Elodea canadensis* is tolerant of lower light, the three duckweed species (*Lemna minor, Spirodela polyrhiza* and *Wolffia columbiana*) float on the water surface and are not dependent on good water clarity.
7) Emergent aquatic plants occurred less frequently in 2008 than in other years, while submergent plants increased greatly in occurrence frequency. While this could suggest that better water clarity allows sunlight to pierce

more areas of the lake, the decline in emergent plants can be a significant detriment to the health of a lake's water. Emergents provide important fish habitat and spawning areas, as well as food and cover for wildlife.

CONCLUSIONS

Based on water clarity, chlorophyll and phosphorus data, Big Roche-a-Cri Lake is a mildly eutrophic lake with good water quality and fair-to-poor water clarity. This trophic state should support significant plant growth and occasional algae blooms.

Overall, filamentous algae occurred at 30.7% of the sites, an increase from the overall occurrence in 2004 of 18%. Filamentous algae declined with increasing depth. Thick films of planktonic algae were also common, especially at the shallower end.

The Simpson's Diversity Index was 0.87, indicating good species diversity. The Aquatic Macrophyte Community Index (AMCI) for Big Roche-a-Cri Lake in 2008 was 54. This value is average quality for lakes in Wisconsin and but lower than the average for lakes in the North Central Region.

There were 23 species of aquatic plants found in Big Roche a Cri Lake in 2008. This number is in the average range for the North Central Hardwood Forests and for Wisconsin Lakes overall. The 7.6% figure for sensitive species places Big Roche a Cri in the lowest quartile for lakes in the North Central Hardwood Forest region, although average for Wisconsin lakes statewide.

The aquatic plant community is characterized by average quality for Wisconsin lakes and good species diversity, but impacted by significant levels of disturbance. Big Roche-a-Cri Lake is one of the lakes in the state quite tolerant of disturbance and far from an undisturbed condition. Disturbances include invasions of exotic species, boat traffic, shoreline development, harvesting and past herbicide treatments.

The aquatic plant community colonized nearly three-quarters of the littoral zone to a maximum depth of 15 feet. The east end of the impoundment had the greatest coverage of aquatic plants. *Vallisneria americana* and *Ceratophyllum demersum* dominate all depth zones and all areas of the lake. The invasive *Myriophyllum spicatum* continued to be a significant presence, although it occurred less frequently and in less density than previous years.

A healthy aquatic plant community plays a vital role within the lake community. This is due to the role plants play in (1) improving water quality; (2) providing valuable habitat resources for fish and wildlife; (3) resisting invasions of non-native species; and (4) checking excessive growth of tolerant species that could crowd out the more sensitive species, thus reducing diversity.

1) Aquatic plant communities improve water quality in many ways:
   - they trap nutrients, debris, and pollutants entering a water body;
   - they absorb and break down some pollutants;
   - they reduce erosion by damping wave action and stabilizing shorelines & lake bottoms;
   - they remove nutrients that would otherwise be available for algal blooms (Engel 1985).

2) Aquatic plant communities provide important fishery and wildlife resources:
- Plants and algae start the food chain that supports many levels of wildlife;
- Plants & algae produce oxygen needed by animals;
- Plants are used as food, cover and nesting/spawning sites by a variety of wildlife and fish;
- Plant cover within the littoral zone of Big Roche-a-Cri Lake is 73.5%, which is within the ideal coverage (25-85%) to support a balanced fishery.

3) Compared to non-vegetated lake bottoms, macrophyte beds support larger, more diverse invertebrate populations that in turn will support larger and more diverse fish and wildlife populations (Engel 1985).

4) Additionally, mixed stands of macrophytes support 3-8 times as many invertebrates and fish as monocultural stands (Engel 1990). Diversity in the plant community creates more microhabitats for the preferences of more species. Macrophyte beds of moderate density support adequate numbers of small fish without restricting the movement of predatory fish (Engel 1990).

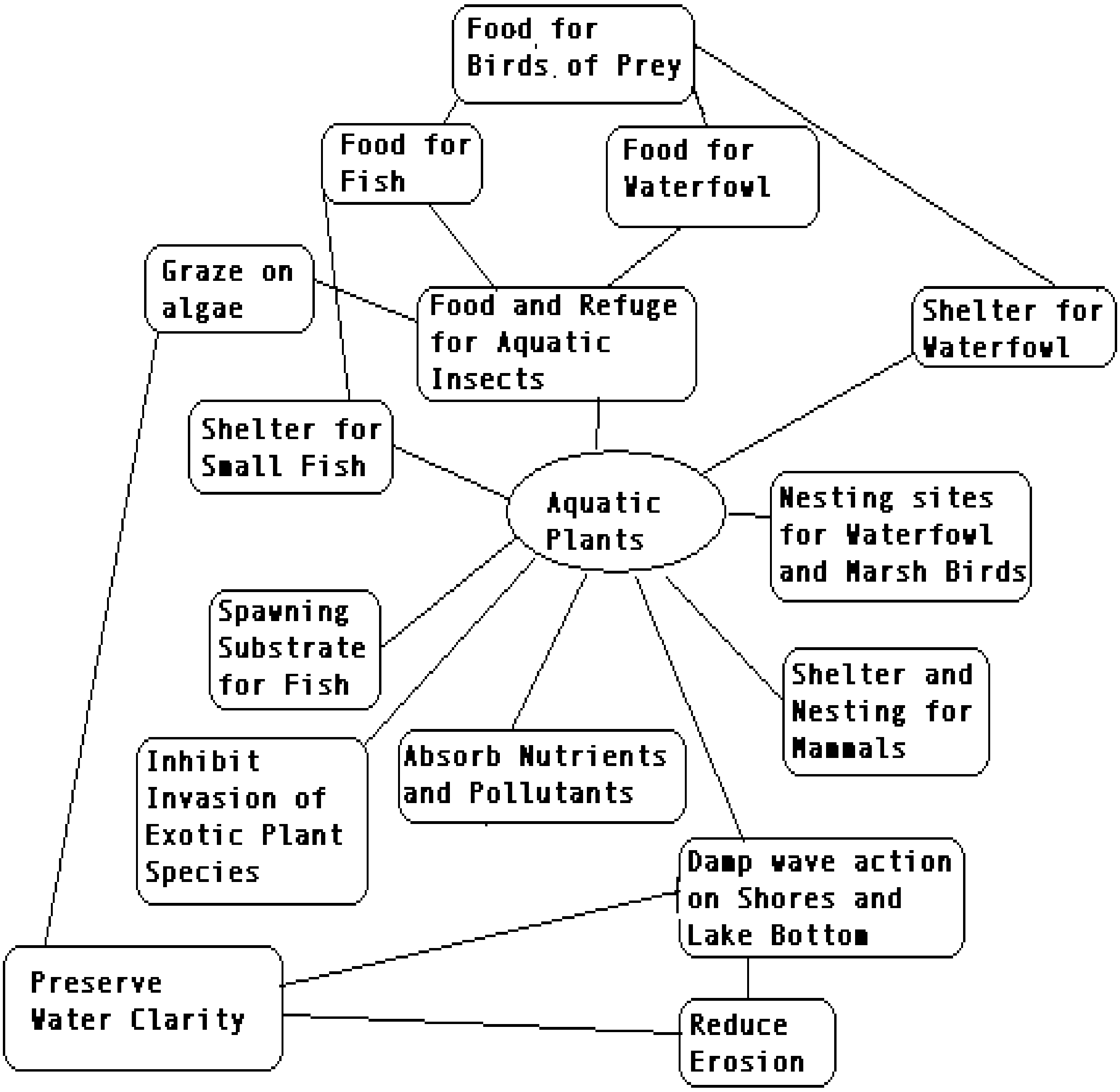


Figure 18: Lake Food Web

Management Recommendations

1) Continue involvement of the Lake District in water quality monitoring through the Citizen Volunteer Lake Monitoring Program.

2) Continue involvement of the Lake District & volunteers in aquatic invasive species monitoring through the Citizen Lake Monitoring Program.

3) Chemical treatments for plant growth are still not recommended in Big Roche-a-Cri Lake due to the undesirable side effects of chemical treatments.

a) The decaying plant material releases nutrients that feed algae growth that further reduce water clarity.
b) The decaying material also enriches the sediments at the site.
c) The herbicides are toxic to an important part of a lake food chain, the invertebrates.
d) Broad-spectrum treatments would open up areas that would be vulnerable to the spread of the exotic species.

4) Continue with natural shoreland restoration. While the amount of restored shoreline has increased since 2004, there is still more to be done and there is still a fair amount of mowed lawn.

a) unmowed native vegetation reduces shoreline erosion and run-off into the lake and filters the run-off that does enter the lake thus reducing nutrient inputs.
a) Shoreline restoration could be a as simple as leaving a band of natural vegetation around the shore by discontinuing mowing.
b) Restoration could be as ambitious as extensive plantings of attractive native wetland species in the water and native grasses, flowers, shrubs and trees on the near shore area.

5) Continue to annually fine-tune the harvest plan and to engage in an integrated approach to the management of the aquatic plants and the aquatic invasives.

a) The mechanical harvesting plan should be designed to remove nutrients, target Eurasian watermilfoil, provide navigation, and recreation where appropriate, prevent the spread of species that could become overabundant and improve habitat.

b) Nutrient reduction. Harvesting removes the nutrients found in the plant tissue and filamentous algae mats. There is evidence that mechanical harvesting may already to be reducing filamentous algae and nutrients.
c) Target Eurasian watermilfoil. The milfoil can be targeted by conducting an early-season harvest and a late-season harvest that cuts only where the milfoil is colonized, cutting the largest and densest milfoil areas first and cutting deep. The incidence of Eurasian watermilfoil has decreased since 2004, suggesting that the integrated approach (harvesting, drawdowns, etc.) is succeeding.
d) It is important that evaluations be conducted on the lake to identify areas of Eurasian watermilfoil before spring harvesting starts. This will allow the fine-tuning of the harvesting map. A second evaluation should be done in the fall, after harvesting has ceased, in order to help identify areas that might need to be examined closely in the spring.
e) If curly-leaf pondweed increases to a nuisance condition, early spring harvesting for this species could be instituted. Skimming off coontail as the harvester is operating will help control this species that is becoming abundant.
f) Provide navigation and recreation where appropriate. Cutting channels through the areas that have the densest plant growth and cutting to control Eurasian watermilfoil will also aid navigation of the lake. Harvesting in the depth zone greater than 10 feet to maintain an open area for higher speed boat traffic would also aid navigation.
g) Prevent the spread of species that could become overabundant. *Vallisneria americana* is one of the few submergent aquatic plants that grow from the base, as grass does. Frequent harvesting in beds of *V. americana* will encourage its growth. Avoid these plant beds when they are not hindering navigation. When *V. americana* is harvested, cut near the sediment, or as deep as the cutter bar extends. The dam end of the lake supports the most *V. americana.* Harvesting the dam end in less than 10 feet should be avoided.
h) Improve habitat. The mid-portion of the lake (area 2) and the 5-10ft depth zone area could be improved the most with channels (not clear-cutting). Cutting channels in this area provides edge needed for habitat and allows the predator fish to better find prey, supporting a more balanced fishery. These open areas are also used by wildlife. The 0-1.5ft depth zone supports the best species richness and diversity. The

only harvesting that should be conducted in this zone are channels next to the docks for land owner access.

6) Continue to cooperate with programs in the watershed to reduce nutrient inputs to the lake. Currently nearly half of the relatively large watershed is in agriculture.

7) Eliminate the use of lawn fertilizers, both organic and inorganic, on properties around the lake.

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